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Arthrofibrosis after ACL reconstruction is best treated in a step-wise approach with early recognition and intervention: a systematic review

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Abstract

Purpose Arthrofibrosis is the most common post-operative complication of anterior cruciate ligament (ACL) reconstruction. Risk factors and management strategies for arthrofibrosis remain unclear. The purpose of this review was to: (a) describe existing definitions of arthrofibrosis, and (b) characterize the management strategies and outcomes of arthrofibrosis treatment.

Methods MEDLINE, EMBASE, and PubMed were searched from database inception to search date (March 21, 2016) and screened in duplicate for relevant studies. Data regarding patient demographics, indications, index surgery, management strategy, and outcomes were collected.

Results Twenty-five studies of primarily level IV evidence (88%) were included. A total of 647 patients (648 knees) with a mean age of 28.2 ± 1.8 years (range 14–62 years) were treated for arthrofibrosis following ACL reconstruction and followed for a mean 30.1 ± 16.9 months (range 2 months–9.6 years). Definitions of arthrofibrosis varied widely and included subjective definitions and the Shelbourne classification system. Patients were treated by one or more of: arthroscopic arthrolysis (570 patients), manipulation under anaesthesia (MUA) (153 patients), oral corticosteroids (31 patients), physiotherapy (81 patients), drop-casting (17 patients), epidural therapy combined with inpatient physiotherapy (six patients), and intra-articular interleukin-1 antagonist injection (four patients). All studies reported improvement in range of motion post-operatively, with statistically significant improvement reported for 306 patients (six studies, p range <0.001 to =0.05), and one study (18 patients) reporting significantly better results if arthrofibrosis was treated within 8 months of reconstruction ($p < 0.03$). The greatest improvements for extension loss were seen with drop-casting (mean 6.2° ± 0.6° improvement), whereas MUA produced the greatest improvement for flexion deficit (mean 47.8° ± 3.3° improvement).

Conclusions Arthrofibrosis is poorly defined and outcome measures range varies widely. Amongst the studies included in this review, arthrofibrosis was most commonly managed surgically by arthroscopic arthrolysis, and most patients showed at least some improvement, including six studies that reported statistically significant change in ROM. In studies that used a step-wise approach to treating arthrofibrosis, more than half of patients were successfully treated without an operation. A more well-defined concept of arthrofibrosis, along with large, prospective studies will provide a clearer understanding of how to describe and manage this complication. The issue of arthrofibrosis following ACL reconstruction is clinically relevant as it represents a common complication of a commonly performed

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operation that nonetheless remains poorly defined and without clear treatment guidelines.
Level of evidence Systematic Review of Level III and IV Studies, Level IV.

Keywords Arthrofibrosis · ACL reconstruction · Joint stiffness · Extension deficit · Rehabilitation

Abbreviations

ACL	Anterior cruciate ligament
ROM	Range of motion
MUA	Manipulation under anaesthesia
PRISMA	Preferred reporting items for systematic review and meta-analysis
AOSSM	American Orthopaedic Society for Sports Medicine
ISAKOS	International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine
ESSKA	European Society for Sports, Traumatology, Knee surgery and Arthroscopy
AAOS	The American Academy of Orthopaedic Surgeons
MINORS	Methodological Index for Non-Randomized Studies
ICC	Intraclass correlation coefficient
CI	Confidence intervals
TKA	Total knee arthroplasty

Introduction

Arthrofibrosis has long been recognized as a common and severe complication of anterior cruciate ligament (ACL) reconstruction, with rates between 4 and 38% reported in the literature [1–3]. Definitions of arthrofibrosis vary widely, and ideal strategies for its prevention and management are unclear. Originally, Shelbourne et al. defined it as a 15° loss of extension and proposed a classification system based on flexion and extension loss, which also considered patellar tightness and the presence or absence of patella baja (ESM Appendix 1). In contrast, Mayr et al. used the definition of scar tissue in at least one compartment causing restricted range of motion (ROM) [4]. Clinically, arthrofibrosis manifests with a symptomatic limitation in ROM of the operative knee [5, 6].

The amount of time between injury and reconstruction has been posited as an important predictor of arthrofibrosis. In an early study, Shelbourne et al. reviewed 169 acute ACL reconstructions, and found that patients who underwent the index surgery less than 21 days after injury had higher rates of arthrofibrosis compared to those who postponed surgery for at least 21 days [6]. Some more recent studies have supported these findings, including two studies that found that patients who underwent reconstruction at least 4 weeks post-injury had lower rates of arthrofibrosis compared to those who underwent surgery earlier [4, 7]. However, other studies have found no differences between those undergoing reconstruction after 4 or 6 weeks post-injury compared to patients with earlier reconstruction [8–10]. Other reported risk factors for arthrofibrosis include female sex, prolonged immobilization and concomitant meniscal repair [10]. Options for the management of post-operative arthrofibrosis include oral corticosteroids, physiotherapy and casting, manipulation under anaesthesia manipulation under anaesthesia (MUA), and operative options including surgical debridement of adhesions [5]. Currently, there exists no evidence-based protocol for the treatment of arthrofibrosis following ACL reconstruction.

The purpose of this review was to: (a) describe existing definitions of arthrofibrosis, and (b) characterize the management strategies and outcomes of arthrofibrosis treatment. It was hypothesized that early intervention would result in better long-term ROM, and that aggressive treatment options including MUA and surgical management would be required for more severe and refractory cases of arthrofibrosis. This systematic review contributes to a better understanding of arthrofibrosis following ACL reconstruction by identifying the need for more consistent definitions, as well as presenting the current best evidence for treatment of arthrofibrosis.

Materials and methods

Search strategy

A systematic search strategy previously described by the authors was employed [11, 12]. Two reviewers searched three online databases (EMBASE, MEDLINE and PubMed) for literature related to the management of arthrofibrosis following ACL reconstruction. The preferred reporting items for systematic review and meta-analysis (PRISMA) guidelines were followed in the development of this study [13]. The search was conducted on March 21, 2016, and included articles from date of database inception to the search date. The research question and individual study eligibility criteria were established a priori. Finally, to minimize publication bias [14], a comprehensive review of the final proceedings from the following recent conferences was performed (2011–2015, inclusive): American Orthopaedic Society for Sports Medicine (AOSSM), International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine (ISAKOS), European Society for Sports, Traumatology, Knee surgery and Arthroscopy (ESSKA), and the American Academy of Orthopaedic Surgeons (AAOS). The

final proceedings for each meeting were retrieved from the respective organizational websites, and a full read-through as well as a search for the keywords "arthrofibrosis" and "ACL" was performed for each program. A total of six potential abstracts were identified, of which one met the inclusion and exclusion criteria for this review.

Inclusion criteria were: (1) all levels of evidence; (2) male and female patients of all ages; (3) studies published in English; (4) human studies; (5) studies reporting how arthrofibrosis after ACL reconstruction was managed and the outcome of management. Exclusion criteria were: (1) non-surgical treatment studies (e.g. conservative treatment, technique articles without outcomes, etc.); (2) patients receiving ACL reconstruction in conjunction with other major surgical procedure, and (3) studies where the outcomes for the exact same patient population were reported in multiple articles, in these cases the most recent article was included; (4) studies reporting complications but not commenting specifically on the management of arthrofibrosis.

The following key terms were used in the search; "ACL", "anterior cruciate ligament", "reconstruction", "repair", "arthroscopy", "arthrofibrosis", "reduced range of motion", "stiffness", and "complication". A table outlining the search strategy is presented in ESM Appendix 2.

Study screening

Two reviewers independently screened the titles, abstracts and full texts of retrieved studies in duplicate (SE, NH). Discrepancies at the title and abstract stages were resolved by automatic inclusion to ensure thoroughness; discrepancies at the full-text stage were resolved by consensus between the reviewers. If a consensus could not be reached a third, more senior reviewer helped to resolve the discrepancy (DD). The references of included studies were screened to capture any articles that may have been missed. A list of included studies can be found in ESM Appendix 3.

Quality assessment of included studies

A quality assessment of included studies was completed using the Methodological Index for Non-Randomized Studies (MINORS) Criteria [15]. MINORS is a validated scoring tool for non-randomized studies (e.g. case reports, case series, cohort studies, etc.). Each of the 12 items in the MINORS criteria is given a score of 0, 1 or 2—with maximum scores of 16 and 24 for non-comparative and comparative studies, respectively.

Data abstraction

Two reviewers independently abstracted relevant data from included articles and recorded these data in a Microsoft Excel (2013) spreadsheet designed a priori. Demographic information included author, year of publication, sample size, study design, level of evidence, patient demographics (i.e. sex, age, etc.) and details of ACL reconstruction performed. In addition, any information regarding the management of arthrofibrosis and the post-operative outcomes, including further surgeries and complications was documented.

Statistical analysis

A kappa (κ) value was calculated for each stage of article screening to evaluate inter-reviewer agreement. Agreement was categorized a priori as follows: $\kappa > 0.60$ to indicate substantial agreement, $0.21 \leq \kappa \leq 0.60$ to indicate moderate agreement, and $\kappa < 0.21$ to indicate slight agreement [16]. Intraclass correlation coefficient (ICC) was used to evaluate inter-reviewer agreement for MINORS evaluation. Descriptive statistics, such as means, ranges, and measures of variance [e.g. standard deviations, 95% confidence intervals (CI)] are presented where applicable. No meta-analysis was performed, as there was high heterogeneity amongst the studies and multiple indirect comparisons. MINORS score was categorized a priori as follows: 0 <MINORS score <6 to indicate very low quality evidence, 6 ≤MINORS score <10 to indicate low quality of evidence, 10 ≤MINORS score <14 to indicate fair quality of evidence, and MINORS score >16 to indicate a relatively good quality of evidence for non-randomized studies.

Results

Study characteristics

Our initial search yielded 2798 studies, of which 25 met the inclusion and exclusion criteria for this review (ESM Appendix 2). Of the 25 included studies, published between 1990 and 2012, there was one case–control study, one prospective comparative study, one retrospective comparative study, seventeen case series, and four case reports (Table 1).

Study quality

There was substantial agreement amongst reviewers at the title ($k = 0.89$; 95% CI 0.86–0.91), abstract ($k = 0.74$; 95% CI 0.64–0.83) and full-text screening ($k = 0.86$; 95% CI 0.73–0.98). The majority of the included studies were

Table 1 Characteristics of included studies

Primary author	Year	Study design	Level of evidence	Patients	Knees	Mean age (years)	Age range (years)	Mean Follow-up (months)
Marzo JM	1992	Case series	IV	18	18	26	N/A	16
Mariani PP	1992	Case series	IV	18	18	24	17–46	6
Rue JPH	2008	Case series	IV	23	23	25.2	14–46	10.4
Mauro CS	2008	Prospective comparative study	III	58	58	26.8	12–56	N/A
Klein W	1994	Case series	IV	32	32	32.7	20–50	22.1
Logerstedt D	2007	Case series	IV	4	4	19	18–20	2.99
Mayr HO	2004	Case series	IV	156	156	37	20–62	51.48
Shelbourne KD	1996	Case series	IV	72	72	25	16–42	35
Muellner T	1999	Prospective comparative study	III	10	10	30	24–50	22
Jackson DW	1990	Case series	IV	13	13	27	N/A	22
Balcarek P	2008	Case report	IV	1	1	24	N/A	24
Rubin LE	2009	Case report	IV	1	1	31	N/A	36
Strum GM	1990	Case series	IV	11	11	27.2	14–45	52.5
Fisher SE	1993	Case series	IV	35	35	24.5	14–39	28
Kamphampati S	2012	Case report	IV	1	1	35	N/A	2
Mohtadi NGH	1991	Case control	III	35	35	24.2	16–43	26
Nuccion SL	2001	Case report	IV	1	1	23	N/A	48
Nwachukwu BU	2011	Case series	IV	53	53	15.6	7–18	14
Millett PJ	1999	Case series	IV	8	8	29	19–43	57
Shelbourne KD	1994	Case series	IV	9	9	23.5	15–36	31
Noyes FR	2000	Case series	IV	23	23	29	14–62	25
Hasan SS	2000	Case series	IV	12	13	27	18–51	46.8
Aglietti P	1995	Case series	IV	31	31	26	18–51	42
Robertson GA	2011	Case series	IV	18	18	31	17–43	6
Magnussen RA	2011	Case series	IV	4	4	30.5	15–56	6

of level IV evidence ($N=22$, 88%). Similarly, there was a substantial level of agreement amongst quality assessment scores using the MINORS criteria (ICC = 0.87; 95% CI 0.78–0.96). The included studies had an average MINORS score of 10.1 ± 2.4, which indicates a fair quality of evidence for non-comparative studies.

Patient demographics

A total of 5415 patients were among the included studies. Of these patients, 648 knees in 647 patients (12% of total patients) were treated for arthrofibrosis after ACL reconstruction and followed for a mean of 30.1 ± 16.9 (range 2 months–9.6 years, one study not reporting follow-up). The combined mean age of patients was 28.2 ± 1.8 years (range 14–62 years). Of 526 patients across 18 studies, 276 were male (52.5% ± 0.05%; six studies not reporting sex distribution). At final follow-up, there were 632 patients were available (98% follow-up rate). The majority of studies (68%, $N=17$) were conducted in North America, with the following distribution: United States: 16 studies; Germany, Italy and the United Kingdom: 2 studies each; Austria, Canada and India: one study each.

Timeline of interventions

The mean time between injury and ACL reconstruction was 4.8 ± 0.8 months (range 1 day–32 years), among nine studies reporting on 147 patients. The mean time between ACL reconstruction and treatment of arthrofibrosis was 12.0 ± 13.0 months (range 31 days–8.8 years), among 21 studies reporting on 565 patients.

Definitions of arthrofibrosis

Nine studies used a subjective definition of arthrofibrosis, including "limited motion", "significant symptoms of pain, stiffness, crepitation, or swelling with activities of daily living", and "functionally significant" loss of ROM. Four studies used an objective classification, the Shelbourne Classification [6]. Four studies based the definition of arthrofibrosis on a relative loss compared with

the contralateral knee. Three studies used the finding of a "cyclops lesion" on magnetic resonance imaging in combination with clinical ROM restriction. Four studies used objective cut-offs to define arthrofibrosis. For extension loss, this ranged from >5° loss to >15° loss. For flexion loss, the cut-offs used were <120° and <90° of flexion. One study did not specify any definition for arthrofibrosis. Eight studies specified a length of time that they allowed post-operatively before applying their respective definition of arthrofibrosis, though this length of time ranged between 4 weeks and 6 months.

Index surgery details

The most commonly used approach for ACL reconstruction was arthroscopic, used in 12 studies (348 patients). The remaining studies used various combinations of open, arthroscopic, and arthroscopically assisted approaches (Table 2). The most commonly used grafts were patellar tendon autografts, which was used exclusively in seven studies (86 patients), and in some patients (exact numbers not consistently reported) in 11 studies (436 patients). The remaining studies used various combinations of allografts and autografts, including hamstring, ilitobial band, and Achilles tendon grafts (Table 3). Five studies (120 patients) did not specify harvest site. Only six studies (111) provided any further detail on the index surgery. In these studies, 32 patients received bio-absorbable screws, 36 received either a bio-absorbable screw or an Endobutton (distributions not specified), 31 patients received a metallic interference screw, and 13 patients received a metallic screw as well as staples. No other surgical details were consistently reported.

Table 2 Summary of approaches used at index surgery

Approach	Number of studies	Number of patients
Arthroscopic only	12	348
Open or arthroscopic	2	67
Arthroscopically assisted	2	35
Open or arthroscopically assisted	1	9
Open only	1	8

Arthrofibrosis management strategies

Five hundred and seventy patients (22 studies) with arthrofibrosis were managed by arthroscopic arthrolysis, 75 of whom underwent MUA either concurrently with arthroscopy or prior to arthroscopy. Seventy-eight patients underwent MUA but did not undergo arthrolysis. Thirty-one patients (two studies) received oral corticosteroids to treat arthrofibrosis, while 81 patients (two studies) underwent specific physiotherapy regimens in an attempt to resolve the arthrofibrosis. Seventeen patients (two studies) were serially casted to encourage return of ROM, while six patients in a single study received continuous epidural anaesthetic in combination with inpatient physiotherapy. Two studies (81 patients) used a targeted, step-wise approach to management of arthrofibrosis, including some or all of physiotherapy (81 patients), drop casting (71 patients), epidural therapy combined with inpatient physiotherapy (6 patients), and oral corticosteroids (8 patients) before progressing to arthroscopic arthrolysis in only 31 patients (38.3%). Four patients (one study) received an intra-articular injection of Anakinra, an interleukin-1 (IL-1) receptor antagonist.

Outcomes

ROM measurements were performed using a goniometer in ten studies (241 patients). The remaining studies did not specify their ROM evaluation method. ROM was reported either as a relative loss (e.g. loss of extension) or recorded as measured (e.g. degrees of flexion). The pre-treatment loss of extension ranged from 1° to 20° (15 studies, 293 patients). The pre-treatment flexion ROM ranged from 81° to 132° (13 studies, 393 patients). After treatment of arthrofibrosis, mean extension loss ranged from 0° to 8.3°, and mean flexion ROM ranged from 111° to 138°. All studies reported improved ROM following treatment. Of seven studies specifying statistical significance, six studies (306 patients) found significant improvement in ROM post-operatively (range $p < 0.001$–$p = 0.05$). One study (18 patients) reported a significantly higher likelihood of "restoring extension loss" if treatment of arthrofibrosis was carried out within 8 months of the reconstruction ($p < 0.03$).

Where possible, outcomes were stratified by management strategy. Studies that used multiple strategies in the same patients but did not separate data for each strategy

Table 3 Summary of graft types used at index surgery

Harvest site	Allograft/autograft	Number of studies	Number of patients
Patellar tendon	Autograft	18	Exact numbers not reported
Hamstrings	Autograft	11	Exact numbers not reported
Iliotibial band	Autograft	1	92
Achilles tendon	Allograft	1	3

were not included. Results are summarized in Table 4. The greatest improvement in extension loss was achieved with drop casting, with a mean improvement of 6.2° ± 0.6° (13 patients). The greatest improvement in flexion was achieved with MUA, resulting in a 47.8° ± 3.3° improvement. Results for other treatment strategies are summarized in Table 4.

Six studies (61 patients) performed and reported the results of biopsies following arthrolysis. All biopsies identified dense fibrous tissue with five studies reporting chondroid metaplasia which was more prevalent in patients whose arthrofibrosis was more chronic. Bony fragments were found within the excised tissue in two patients. No studies reported inflammatory changes, with two studies (28 patients) specifically commenting on their absence.

Complications

Across 22 studies employing operative techniques to manage arthrofibrosis, no cases of infection, fracture, thromboembolism, or any other complications were reported. Of patients who underwent arthroscopic arthrolysis, 37 patients (6%) underwent a total of 42 subsequent arthroscopic procedures for persistent ROM deficits. Three patients underwent three additional surgeries that were unrelated to ROM deficits (one for a new injury, two for degenerative changes).

Discussion

The key finding from this review is that even though arthrofibrosis after ACL reconstruction is a poorly defined complication lacking in high-quality literature, most patients show at least some improvement after management, with six studies reporting statistically significant improvement. Furthermore, much greater improvements are achieved in flexion loss as compared to extension deficits. Treatment primarily consists of surgical management, most commonly in the form of arthroscopic arthrolysis. Other treatments for arthrofibrosis include physiotherapy, serial casting, oral corticosteroids, IL-1 receptor antagonists, and MUA. Based on the studies included in this review, the greatest improvements for extension loss were seen with drop-casting and arthroscopic arthrolysis, whereas the greatest improvements for flexion loss were in patients who underwent MUA followed by arthrolysis. Due to the heterogeneity of the patients included, variety of outcome measures used, and large differences in sample sizes, it was not possible to directly compare these outcome differences. These key findings were consistent with those from the top 20% of included studies in terms of quality (i.e. MINORS score). Interestingly, this subset of relatively higher quality studies shared two important characteristics: all studies defined arthrofibrosis objectively in terms of ROM cut-offs, and all studies used an algorithmic approach to treating arthrofibrosis based on severity, presentation, etc.

The second key finding in this systematic review is that there is a lack of consistency in defining arthrofibrosis in the literature. For this reason it is often unclear how severe the arthrofibrosis was in patients prior to undergoing treatment. The studies included in this review used definitions ranging from subjective restriction of motion, to objective ROM cut-offs and imaging criteria. We propose that future studies define arthrofibrosis after ACL reconstruction using the original Shelbourne Classification (ESM Appendix 1) [17]. This classification system is already in use (used by four studies included in this review), is based on a measurement which is both objective and easy to obtain (ROM), is based on a comparison with the contralateral knee which allows for consideration of variations in baseline ROM, allows for an understanding of severity, and correlates well with patients' subjective assessment of their knee function [17].

The studies included in this review took one of two broad approaches to managing arthrofibrosis: some studies prescribed routine post-operative rehabilitation for all patients and treated any patients who failed to regain ROM surgically, whereas other studies took an algorithmic approach to treatment, whereby these patients would be treated first with some combination of aggressive physiotherapy, drop-casting, and MUA. Based on the findings of this review, there are at least some patients

Table 4 Outcomes stratified by management strategy

	Patients	Studies	Pre-treatment		Post-treatment		Mean change	
			Extension loss (°)	Flexion ROM (°)	Extension loss (°)	Flexion ROM (°)	Extension (°)	Flexion (°)
Arthroscopic arthrolysis	400	16	−2.7	110.3	0.9	132.3	3.6	22.0
Corticosteroids	23	1	−0.7	118.7	0.6	120.8	1.3	2.1
Casting	13	2	−7.5	119.2	−1.3	125.8	6.2	6.6
Manipulation under anesthesia	46	2	0.00	94.3	2.4	142.1	2.4	47.8

who can regain ROM without surgical intervention. At the same time, due to the wide range of timelines in the included studies, it is unclear how important time to arthrolysis is in ensuring return of ROM. Thus, the authors recommend that an intensive algorithmic approach be taken to the treatment of arthrofibrosis, whereby ROM deficits are recognized early, within the first 3 months post-operatively, and treated with a short course of intensive physical therapy, drop casting, and oral corticosteroids. After a brief trial of this regimen, non-responsive patients should be offered MUA +/− arthroscopic arthrolysis. In the two included studies that used a similar algorithmic approach, over 60% of patients were successfully managed without an operation [18, 19].

In the development of such a treatment algorithm, it may helpful to look into the management of arthrofibrosis in patients undergoing total knee arthroplasty (TKA). Similar to ACL reconstruction, post-operative arthrofibrosis is a common complication of TKA [20]. A recent review [21] highlights the most important tenets of treating post-TKA arthrofibrosis as follows: in the acute post-operative period, physiotherapy, optimal pain control, and progressive splinting (especially for extension) are the mainstays of treatment. MUA is recommended within 2–3 months of the index TKA, and results may be improved with intra-articular or epidural infusion of anaesthetic and/or analgesic agents. Finally, if MUA has not been performed within 3 months or is unsuccessful, arthroscopic arthrolysis is recommended [21]. That being said there are some key differences between ACL reconstruction and TKA including the fact that TKA is an open procedure. Furthermore, in the case of ACL reconstruction, a malpositioned graft may be the cause for flexion or extension limitations andsurgeons must be careful to identify the correct etiology of these range of motion limitations prior to intervening. Therefore, one must apply caution when extrapolating literature on the management of arthrofibrosis after TKA.

In the patients included in this review, no specific risk factors were identified for the development of arthrofibrosis. There was preponderance towards arthroscopic approach in the index surgery, though this may simply represent the fact that this is the most common approach for ACL reconstruction [22]. Female sex has been proposed as a risk factor for developing arthrofibrosis in some previous literature [10, 23], though other studies have not found this [24]. The studies included in this review had a roughly equal sex distribution among patients developing arthrofibrosis. Finally, the use of patellar tendon autografts was identified by one of the included studies as a risk factor for the development of arthrofibrosis [10], though it has not been directly compared to other graft types in a controlled study.

The strengths of this review included its expansive search strategy search strategy and the inclusion of studies regardless of date of publication, patient sex, age, or management strategy. Two reviewers screened all articles independently at each stage, which served to minimize reviewer bias. As well, though the studies were hetergoenous in terms of outcome reporting and definitions of arthrofibrosis, the patient populations were relatively similar, particularly as it pertains to important diagnostic factors (e.g. sex, age time to ACL reconstruction). Interestingly, to the authors' knowledge, this is the first systematic review looking specifically at arthrofibrosis following ACL reconstruction. Finally, over 97% of patients were available for follow-up in all included studies.

This review had some limitations, primarily related to the quality of evidence available, which was mostly Level III and Level IV studies. Furthermore, given the variety of definitions of arthrofibrosis used in the studies, it was often unclear how severe the patients ROM limitations were prior to treatment. Furthermore, the significant heterogeneity and lack of comparative studies made performing a meta-analysis unfeasible. Another limitation was the exclusion of any studies not available in English, may result in some selection bias. Lastly, many studies which included surgical management as part of their treatment after non-surgical management of arthrofibrosis only reported outcomes after arthrolysis and failed to report how much, if any, improvement in ROM was observed after the non-operative treatment.

Future studies should define arthrofibrosis more precisely, and the authors propose the use of the Shelbourne Classification (ESM Appendix 1). A consensus definition that correlates well with functional limitations would be ideal. In addition, studies specifically looking at arthrofibrosis after ACL reconstruction should compare patient, surgical, and post-operative risk factors among matched patients. Specifically, prospective studies that randomize matched patients into different groups based factors such as on time to surgery, graft type, and post-operative rehabilitation and compare rates of arthrofibrosis would be the most well placed to provide answers about risk factors. Furthermore, this paper was not aimed at examining specific patient factors, such as medical and socioeconomical, which may contribute to the development of arthrofibrosis. Future prospective studies should examine such potential links. Finally, future studies should provide detailed descriptions of the index operation if available, either within the article or as an appendix. Due to a lack of surgical technique detail, this review was not able to examine the importance of such factors as open vs. arthroscopic approach in the development of arthrofibrosis.

Conclusions

Arthrofibrosis is poorly defined and outcome measures range vary widely. Amongst the studies included in this review, arthrofibrosis was most commonly managed surgically by arthroscopic arthrolysis, and most patients showed at least some improvement, including six studies that reported statistically significant change in ROM. In studies that used a step-wise approach to treating arthrofibrosis, more than half of patients were successfully treated without an operation. A more well-defined concept of arthrofibrosis, along with large, prospective studies will provide a clearer understanding of how to describe and manage this complication.

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Authors' contributions SE and CEH carried out the search, screening process, and assessment of study quality. SE drafted the manuscript. CEH edited the manuscript. ORA and DD conceived the study, and provided key expert input and editing throughout the process. MTH, RO, and DBW edited the manuscript and provided key expert input. DBW and RLB carried out a comprehensive search of recent orthopaedic meetings to minimize publication bias. NS provided feedback on methodological and statistical aspects. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest The authors of this paper declare no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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